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CONTRIBUTIONS TO THE ANALYSIS AND SYNTHESIS OF KNOWLEDGE

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THE ORIGIN OF THE SEPARATION BETWEEN SCIENCE AND PHILOSOPHY

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1. De Broglie and Einstein on Science and Philosophy

When it comes to the question of science and philosophy, the average college student and even the average college professor are isolationists. Physical science is one department, and philosophy is another. They appear to have little in common. If one were to say that in order really to understand his own field the physicist or biologist needs to know something about philosophy and the philosopher needs to know something about science, most people would be quite surprised and probably somewhat incredulous. And yet the isolationist attitude on this subject so common among our college population, students and faculty alike, is not shared by the most creative scientific minds of our age. Certainly it was not the attitude of past generations: for centuries the unity of philosophy and science was taken for granted. But a belief in their unity is not the exclusive property of the past. The men who have laid the two cornerstones of physical science in the twentieth century — the wave theory of matter and the theory of relativity — can testify instead.

Prince Louis de Broglie, author of the wave theory of matter, writes in his book, *The Future of Physics*:

> In the nineteenth century, there came into being a divórce between scientists and philosophers. The scientists looked with a certain suspicion upon philosophic speculations which appeared to them too frequently to lack precise formulation and to attack vain, insoluble problems. The philosophers, in turn, were no longer interested in the special sciences because their results seemed too narrow. This separation, however, has been harmful to both philosophers and scientists.

Albert Einstein, author of the theory of relativity, writes:

> I can say with certainty that the ablest students whom I met as a teacher were deeply interested in the theory of knowledge. I mean by "ablest students" those who

excelled not only in skill but in independence of judgment. They liked to start discussions about the aims and methods of science, and proved by their obstinacy in the defense of their opinions that this issue was an important one to them.

Niels Bohr, to whom we owe our present views about the structure of the atom, might easily be quoted in the same vein. It is he who advanced the basic principle of subatomic physics — the principle of complementarity.

In spite of what these three great men hold to be true regarding the interdependence of science and philosophy, in actual practice the gap remains. The two fields are taught separately, and research in them is pursued separately. We mentioned before that this has not always been the case. Initially, science and philosophy were one, and they drifted apart only by a gradual process. Let us see whether we can follow this process:

2. Science and Technology

Everyone who is at all familiar with science knows that science provides us with information about how to repair a radio set, how to grow corn, how to produce atom bombs, etc. But this kind of information does not exhaust what we can learn from science. For example: something is wrong with your radio, and there are two people whom you could ask to repair it: one is the janitor, who happens to know a good deal about your particular make of radio; the other is a physics professor whose particular specialty has almost nothing to do with radios. If you want the job done quickly you will ask the janitor — he has the technical "know-how". On the other hand, the professor knows something which the janitor does not know, namely, the fundamentals of electromagnetism. Hence, if you allow him sufficient time he will find out how to apply his knowledge of electromagnetism to the repair of your radio set. Not only that, but he will then be able to take care of all types of radio sets, and all sorts of other electrical devices as well, such as short-wave generators, cyclotrons, Geiger counters, etc. The janitor in this case is a technologist; the professor is a scientist.

The British mathematician W. K. Clifford made a very lucid and precise distinction between science and technology in one of his lectures:

> Now it seems to me that the difference between scientific and merely technical thought is this: Both make use of experiment and direct human action; but while technical thought or skill enables a man to deal with the same circumstances that he has met with before, scientific thought enables him to deal with different circumstances that he has never met before. . . . The aim of scientific thought is to apply past experience to new circumstances.

The question now arises: what instrument can we use to apply past experiences to those new circumstances, the circumstances we meet in the future? It becomes obvious that there can be no instrument whatever unless we assume that the future will in a certain manner resemble the past. Clifford says:

> The instrument is an observed uniformity in the course of events. By the use of this instrument it gives us information transcending our experience; it enables us to infer things that we have not seen from things that we have seen.

To work on the production of this instrument means to study the uniformities in nature, and this work is called "scientific research." The difference between science and technology is that science encompasses a wider range of uniformities. To technology belong the uniformities which are used to repair a special make of radio; but the uniformities which we find in all electromagnetic phenomena belong to science.

3. The Natural Path of Investigation

Anyone who has worked in science, not only to open a door to technology but also to search for the uniformities or laws of nature, has felt the urge to proceed to laws of higher and higher generality. When research is carried forward to its limits, one occasionally comes upon questions which are not the property of any of the "special" sciences, such as physics, psychology, or economics. One is led to investigate the properties of space and time, the relation between cause and effect, the reasons for uniformity in nature, the relation between our sense perceptions and underlying physical reality, the coexistence of human "freedom" and "iron" physical causality. There is some doubt

as to whether all these questions belong in the domain of "bona fide" science. Without deciding this issue one way or the other, we can say for the time being that this kind of question belongs to a field known in our vague, everyday language as "philosophy."

Thus there is a path which leads from technology to science and from science to philosophy. We can describe it in simple terms by saying that it is a gradually increasing unification of our knowledge. This is the way it was described by the British philosopher, Herbert Spencer: "Knowledge of the lowest kind is ununified knowledge; science is partially unified knowledge; philosophy is completely unified knowledge."

Science, then, starts as observation and experiment, and winds up as a system of abstract concepts and principles. The Greek philosopher Aristotle gives us a good notion of how this happens:

> The natural path of investigation starts from what is more readily knowable and more evident *to us* and proceeds to what is more self-evident and intrinsically more intelligible; for it is one thing to be knowable to us and quite another thing to be intelligible objectively. This, then, is the method prescribed: to advance from what is clearer to us, though intrinsically more obscure, towards what is intrinsically clearer and more intelligible.

Before we can understand the relation between science and philosophy, we must understand this distinction which Aristotle makes between what is "more readily knowable to us" and what is "intrinsically more intelligible." When Aristotle says that something is "clear and knowable to us," he means that it is "clear to our immediate sense experience." But to Aristotle immediate sense impressions are crude and "general." It is only when they have been subjected to careful analysis that they can be reduced to their objectively simple elements or "particulars."

> Now what is plain and obvious at first are rather confused aggregates, the elements and principles of which become known to us later by analysis. Thus we must advance from generalities to particulars, for it is a whole which is best known to sense perceptions and a generality is a kind of a whole, comprehending many things within its parts.

4. "Direct Knowledge" and "Intelligible Concepts"

Aristotle calls a concept "intelligible intrinsically" if it is more useful in the formulation of simple laws of nature than are crude sense impressions. We may explain this concept of "intelligibility" with an example taken from elementary mechanics. We are observing a material body, say a ball, falling to the ground from a height. At the same time, we have a clock. Our crude sense perceptions tell us that between the act of dropping the ball and the moment when it hits the ground, the hands of the clock have advanced. We might drop other objects, such as stones or apples, at different times, in different places and from different heights — yet casual observation alone would not necessarily lead us to note any uniformity in the motions of these falling bodies, except perhaps that the farther they fell the faster they fell. Galileo, however, went farther; he conducted experiments, and through his analysis of the results he was able to formulate the concepts which enable us to describe the motions of falling bodies — acceleration and resistance. With the aid of these concepts, it is possible to describe very simply the two extreme cases: in very thin air, acceleration is constant; in very dense air, resistance is so high that acceleration reaches the vanishing point. But we must go still farther; in order to define the concept of acceleration for all possible motions, we must define the concept of velocity, and in order to do this we require the concept of the differential coefficient of a function. All the concepts needed to describe motion — the instant of time, acceleration, differential coefficient, velocity — are "intelligible" to our reason and "intrinsically" clear. But to our immediate sense perception they are obviously obscure.

Let us take another example from modern physics. When an atom bomb explodes we see a cloud shaped like a mushroom — this is knowable to us by immediate sense perception. But there is another way of describing that explosion, namely Einstein's formula for the conversion of mass into energy, $E=mc^2$. The concepts Energy (E) and mass (m) are "intelligible" to our reason, but they are anything but clear to our immediate sense perception.

This contrast between the results of direct sense observation and the results of rational analysis has dominated the philosophy of science as long as any science has existed. The two concepts of "what is simple and knowable to us" and "what is obscure to us" have been the source of great intellectual struggles, and

it is from the discussions centering about this contrast that modern science and its philosophical interpretation have developed. As long as men have sought knowledge, they have sought a few simple principles which would explain logically the enormous complexity of observable facts. But this search has never failed to be accompanied by great distrust of abstract knowledge — a distrust born of the fear that formulae might never exhaust the richness of the actual world.

There has always been a "scientific" type of man, who needs only to acquire a few principles from which observable facts can be logically derived in order to feel that he "understands the world." But there has also always existed the kind of man who achieves this feeling of understanding when he surrenders as passively as possible to the flow of sense impressions received from the actual world. These two approaches are described by F. S. C. Northrop as "the Western and the Eastern type of thought."

5. "Science" and "Philosophy" Were Once One and the Same

For the ancient Greeks, every investigation which led from immediate sense experience to the abstract principles from which this experience could be derived was called "science" or "philosophy." There was not much differentiation between the meanings of these two terms. A recent French philosophical dictionary gives as its first meaning for the word "philosophy" that ancient definition: "rational knowledge, science in the most general sense of the word."

As a matter of fact, it is characteristic of all languages whose scientific vocabulary, like that of English, is based upon the Greek that there has in the past been very little distinction in meaning between "science" and "philosophy." In the writings of Aristotle, systems of knowledge about inanimate bodies (physics), animate beings (biology), and human societies (politics) were treated as part of "philosophy" or "science." The same broad meaning prevailed during the Middle Ages. A modern author whose philosophy is constructed along the lines of medieval Thomism defines philosophy as follows: "Philosophy is the scientific knowledge of all things, gained through consideration by the natural light of reason of their fundamental reasons and causes." In this definition there is a phrase which Aristotle would never have used in the same sense — "the natural light of reason." This expression, so characteristically medieval, im-

plies that philosophy is not the only kind of knowledge, that there are other kinds which must be acquired by other means.

Even today, of course, the broader use of the word "philosophy" has not disappeared. Our universities use it all the time in awarding the degree of "Doctor of Philosophy" to students who have fulfilled their requirements in one of the special sciences.

6. "Science" and "Sacred Doctrine"

The medieval philosophers used the word "science" in a sense which is more general than that of "philosophy." "Science" includes not only the "philosophical knowledge" which is "gained by human reason" but also "sacred doctrine" which can be obtained only by "divine revelation." St. Thomas Aquinas, the leading philosopher of the Middle Ages, raises directly the question whether "sacred doctrine" belongs in the realm of "science", a question which he answers in the affirmative. Man can obtain knowledge about the existence and the properties of God by the light of his own reason, says St. Thomas but

> even as regards those truths about God which human reason can investigate, it was necessary that man be taught by divine revelation. For the truth about God, such as reason can know it, would only be known by few and with the admixture of many errors.

In other words, there are a great many things about God and the world which we know by revelation, and could not know without it. Medieval writers, as well as a great many later ones, distinguished, therefore, between "natural" or "philosophical" theology on the one hand, and "sacred" theology, derived from revelation, on the other. Thomas Aquinas attempts to demonstrate that "science" comprises both "natural theology" and "sacred doctrine," but that philosophy pertains only to "natural theology." It might be said of the Middle Ages, then, that science and philosophy are not the same; rather, science *includes* philosophy.

7. Medieval Roots of Empiricism

In the late Middle Ages there arose a new philosophical movement which was to represent the transition from medieval to modern thought. The significant feature of this movement was that, while in principle it was based on the Aristotelian and

Thomistic patterns of thought, it gave much greater emphasis to the role of experience in science. This does not mean that there was a complete break with the older philosophers. The new movement still attributed paramount importance to "revelation" or "revealed truth." But a new element had without doubt been introduced, as we can see from the following excerpt from the writings of Roger Bacon:

> There are two ways of acquiring knowledge: namely by argumentation and by experience. Argumentation arrives at a conclusion and makes us agree with it. But argumentation does not banish doubt so effectively that the mind rests in intuition of the truth, until the truth is discovered by way of experience. . . . If someone who has never seen fire has worked out an adequate proof that fire injures and destroys things yet the mind of the student would never be content with this demonstration, nor would he avoid contact with flames. But once the experience of combustion has been had the mind is reassured and rests content in the splendor of the truth. . . . All statements must therefore be confirmed by way of experience. But experience is twofold. One type is attained by external sense perception. Moreover, what occurs in regions other than those where we are situated we learn from reports from other savants who have experienced them. This type of experience is natural to man and belongs to philosophy.

Roger Bacon assigns to philosophy all human knowledge which man obtains from his natural reason and natural experience. Nevertheless he believed, as Thomas Aquinas did, that there was also a science transcending natural experience and reason, which was based on experience of a different sort.

Bacon stresses the point that natural experience is inadequate for man. First,

> because it does not give complete assurance about his knowledge of material things, which are difficult to understand and secondly, because it provides no evidence at all about spiritual things. . . . It is, therefore, indispensable that the human mind receive some assistance in some other way. And this is the way the holy patriarchs and prophets who first brought science to the world received interior illumination and did not rely only upon sense evidence.

The remarkable thing about Roger Bacon was that his emphasis on the importance of experience and his distrust of pure reasoning seem to have led him to greater confidence in "interior illumination" or "divine revelation." But it must be remembered that "experience" for Bacon meant not only sense experience but also "supernatural" experience — and both for him were more reliable than what he called argumentation. This correlation between a strong emphasis on personal experience and a belief in supernatural phenomena has appeared again and again in intellectual history, as we shall see later on.

8. Descartes and the "Tree of Philosophy"

The period around 1600 marked the "birth of modern science and philosophy," and just as antiquity had its Aristotle and the Middle Ages its Thomas Aquinas, so René Descartes was the writer who formulated for his time the general principles of the new science. In the preface to his *Principles of Philosophy*, the French philosopher and scientist used the famous image of the tree to illustrate his ideas about the structure of science and philosophy.

> All philosophy is like a tree, of which metaphysics is the root, physics the trunk and all the other sciences the branches that grow out of the trunk. They are reduced to three principal ones, namely: medicine, mechanics, and ethics.

The image of the Cartesian tree may be translated into more familiar terms: the roots (metaphysics) are the most general philosophical principles which originate in introspection; they deal with the reality of the external world, space and time, etc. The trunk (physics) comprises the laws governing the physical world, such as the conservation of mass, momentum, and energy, the laws of motion, etc., while the branches are applied science: the practical applications of general scientific principles to mechanical engineering, to the art of healing, and to the rules of human behavior. Descartes continues:

> As it is not from the roots or trunks of trees that we gather the fruit but only from the extremities of the branches, so the principal utility of philosophy depends on the separate uses of its parts which we can only learn last of all.

It is important to note that Descartes did not ascribe any utility to general principles alone; they had to be checked through their observable consequences or "fruits." These "fruits" of the tree are the technological applications of scientific knowledge to human labor, human health and human conduct. Thus the Cartesian tree embraces "science" or "philosophy" in the ancient sense; it contains all the stages of unified knowledge, from the practice of everyday life to the abstract principles of metaphysics.

9. The Empirical Knowledge of the Craftsman

Attempts were undoubtedly made in antiquity and in the Middle Ages to draw conclusions from the generally accepted principles of philosophy which might make human life more comfortable and pleasant. Whatever theoretical principles were espoused concerning the nature of inanimate bodies ought to have furnished a few practical principles which could be used in building and engineering. Theories about the nature of animate beings ought to have led to some helpful contributions to the art of medicine. But actually, with all the principles announced during all these centuries, there was very little that was logically cogent or practically useful derived from them. Only in the field of astronomy, and to a lesser degree in the field of medicine, did there exist a certain body of knowledge which was at the same time practically useful and based on philosophical principles. But even in these fields, the bond between principle and fact was hardly strong, as we shall see when we try to understand the Copernican revolution in astronomy. Suffice it to say that before 1600, before the "birth of modern science and philosophy," the crop of fruits from the tree of philosophy was a fairly meager one.

On the other hand, the ancient Greeks and Romans and the ancient Egyptians displayed a marvelous art and skill in building and even in mechanical engineering. Their vaults and arches which bore such heavy loads were constructed with such precision and strength that they indicate a highly sophisticated knowledge of practical mechanics. Be this as it may, the knowledge of these ancient builders and engineers was not scientific but technological. It was purely empirical, not based upon philosophical principles. The contrast between the modern and the ancient approach to technical knowledge is described by a professor at the school of applied engineering in contemporary Rome:

> What modern science and industry accomplish by laboratory research tests, theoretical hypotheses expressed in formulae . . . was accomplished for the science and industry of ancient times by the transmission of technical knowledge . . . and by empirical formulae, jealously guarded and handed down in mysterious symbolic form.

10. Practical Mechanics in Ancient Rome

One of the very few books on technology which has been preserved from ancient Rome is Vitruvius' book on architecture, a work which gives us a fairly clear idea of technical "know-how" among the Romans. Vitruvius discusses the mechanical devices which were used in building to hoist heavy loads, giving the most precise directions on how to construct systems of axles and wheels, pulleys and levers, in order to obtain a machine which would save labor. He defines a machine as "a continuous material system having special fitness for the moving of weights." He also describes machines which launched projectiles to be used for military purposes. With the greatest accuracy and with the occasional use of mathematical calculation, he offers detailed descriptions of complicated systems of pulleys and levers. Still, the labor saving effect of these machines is an empirical matter, a matter of experience, and there is hardly any attempt made to derive concrete results from general physical laws. Every once in a while, however, Vitruvius hints that behind the operations of these mechanical devices, there may be universal laws of nature.

> All machinery, he says, is generated by Nature and the revolution of the Universe guides and controls. Since our fathers have observed the revolutions of the sun and the planets they took precedents from Nature, imitating them, and led on by what is divine they developed the comfort of life by their inventions. And so, they rendered things more convenient by machines and their revolutions.

Vitruvius says of the lever, "The short end of the lever is placed under the load, and the long end of the lever, when it is pressed down by one man's strength, raises the load." He understood how a lever could be used to lift loads which were too heavy for the strength of one man. And yet this understanding is based not on the laws of equilibrium on the lever, which had

been established before his time by Archimedes, but rather on his own intuitive insights acquired through practice. He attempts a crude explanation: "When the lever is in action the circular motion of the lever round the fulcrum causes the weight of a great load to be balanced by few hands." This "rule of thumb," this expression of what the Roman engineer *felt* to be true, is probably what later developed into the "principle of virtual displacements." But apparently the greatest extent to which the Romans related the power of the lever to the rest of nature was in their "feeling" that the use of rotating bodies was a kind of imitation of the revolution of the planets.

11. The Low Social Status of Empirical Investigation in Ancient Greece

The wide gap which existed throughout antiquity and the Middle Ages between "principles" and "know-how," between "science" and "technology," was intimately connected with the social structure. The "know-how" of the craftsman and the engineer was acquired through physical work, not through pure intellectual effort. It was the empirical knowledge of the man of low social status, the artisan and even the slave. Philosophical knowledge was cultivated and promoted by men of high social status, in particular priests and statesmen. The "lower" strata collected "facts"; the higher-ups advanced principles. Contact between the two types of knowledge was discouraged by social custom. If a man of high social status attempted to apply his "philosophy" or "science" to the work of the craftsman, he was ostracized.

A case in point is that of the great Greek mathematician Archimedes, whose name is known to every student of high school physics who has learned "Archimedes' principle" of hydrodynamics. Another contribution of his, mentioned above, was the law of equilibrium on the lever, which he derived from what he believed to be self-evident principles. But he did not restrict himself to this "philosophical" or "scientific" work; he saw that his "law of the lever" had applications, and he applied it to the construction of machines which could lift heavy loads by the exertion of a small amount of force. During the siege of his native city of Syracuse, Archimedes acted as scientific adviser to the armed forces of Syracuse, for he furnished directions for the building of machines which could hoist the enemy fighting vessels right out of the water and render them ineffectual. Some-

thing extraordinary had taken place: "pure science" had been put in the service of practical warfare.

The scientists and philosophers disapproved. This putting of scientific abilities to practical use meant a degradation of standards. The Greek biographer Plutarch writes about Archimedes: "He did not think the invention of engines for military purposes an object worthy of his serious studies, but only reckoned them among the amusements of geometry." For Plutarch, Archimedes was like those Greek mathematicians whose chief concern was the demonstration of geometrical theorems, but who happened to employ mechanical instruments of measurement to do so, instead of pure logical deduction. This view of philosophy and its relation to the social order had been crystallized by Plato, who placed philosophy high above empirical knowledge and technical application; he took strong exception to scientists who attempted to confirm their theorems by testing their consequences in the external world through sense observation. "Plato inveighed against them with great indignation," writes Plutarch, "as corrupting and debasing the excellency of geometry, by making her descend from incorporeal and intellectual to corporeal and sensible things."

The inferior status of technology or technical application mirrored the inferior social status of the working man in Greek society. Plutarch attributes to Plato the statement that who applies mechanical instruments in geometry has "to make use of matter, which requires much manual labor and is the object of servile trade."

When mechanics as a system of knowledge became connected with technical application it was, according to Plutarch, "separated from geometry and being a long time despised by the philosophers was considered as a brand of military art."

When we compare the modern period with antiquity and the Middle Ages, we see that each era had its barriers, its "gaps." But whereas today there is a gap between science and philosophy, in ancient and medieval times it was science and philosophy on one side arrayed against empirical or technical knowledge on the other.

12. How "Modern Science" Was Born

One of the greatest of modern philosophers, A. N. Whitehead, writes:

> All the world over and at all times there have been practical men, absorbed in irreducible and stubborn

> facts; all the world over and at all times there have been men of philosophic temperament, who have been absorbed in the weaving of general principles.

During ancient and medieval times these two kinds of men had little to do with each other. Whitehead holds that the "birth of modern science" is closely connected with the beginnings of cooperation between them.

> The union of passionate interest in the detailed facts with equal devotion to abstract generalization forms the novelty in our present society. Previously it had appeared sporadically and as if by chance.

Archimedes' application of mathematics to engineering was the kind of sporadic event Whitehead refers to. In our society, this "balance of mind" has now become an essential factor in our cultural tradition. "It is," says Whitehead, "the salt which keeps life sweet." Following from this, Whitehead's understanding of the part education ought to play in the modern world is expressed clearly and wisely: the role of the university is "to transmit the interest in the relation of general principles to stubborn facts from generation to generation."

Around 1600, there was a shifting of class structure; the distance between the craftsman and the statesman was narrowed. The breaking down of social barriers was accompanied by an increasing closeness between interest in principles and interest in facts. There was a new balance of mind, a new science which undertook to establish general principles which would serve the needs of practical mechanics and medicine. The birth of modern science meant the development of the law of inertia and the law of gravity, and from these and other principles the men of the new era were able to leave behind the "rule of thumb" and to derive logically the practical steps to be taken in dealing with "stubborn facts." Not only could they hoist heavy loads, but they could introduce precision into many new activities from the making of clocks to the aiming of cannon balls.

13. The Beginning of the Split Between Science and Philosophy

"Philosophy" or "science" in its original broad sense had now become an endeavor of extreme complexity. It had to do more than set up principles which were "intrinsically intelligible"; these principles had to be such that results could be derived from them which would aid the engineer in building

domes and bridges. Little wonder that cracks and breaks developed in the long chain of propositions needed to connect the philosopher's principles with the craftsman's "know-how." The first conspicuous break occurred in astronomy. Actually, this was to be expected, for even in antiquity astronomy had touched both philosophical principle and empirical fact. There was an intelligible theory about the stars in the sphere, but ancient astronomers were also able to derive the positions of the stars and to check them by observations.

When the demands of modern science forced stricter agreement between principle and fact, however, astronomers were faced with a dilemma. Which is more important to require: that the principles from which we start to be "intelligible" and "intrinsically knowable," or that the results of these principles agree with the facts as they are observed? For it was becoming more and more obvious that both requirements could not be met at once.

The alternative had already been explicitly formulated by the ancient Greeks. They accepted without question the hypothesis that celestial bodies move in concentric circular orbits around the earth, while the earth itself remains stationary at the center of the universe. This principle was "intelligible" because the circle was regarded as the most perfect curve and celestial bodies as the most perfect beings, unchangeable and eternal. Therefore, their movement, in order to be consistent with their nature, had to follow (the philosophers thought) the perfect and unchanging circular orbit. But the astronomers of Plato's time knew very well that accurate observation of the sun and the planets and their positions was not consistent with the hypothesis of the concentric circles.

Two instances of this inconsistency are the position of the sun and that of the planets. Let us assume that the sun actually moves around the earth along a perfectly circular orbit at constant speed. In that case, its position in the sky as we see it ought to advance each day by an equal distance along the sphere, in other words, by an equal angle. But the Greeks knew for a fact that this angle really varies at different seasons of the year. The hypothesis does not gibe with the facts. The planet Jupiter completes an approximate circle every twelve years, but study reveals that it describes a small loop along the circle every year; this means that Jupiter has a period of "retrograde motion" twelve times a year. These "irregularities" in the positions of the sun and the planets are in conflict with the principle of concentric circles.

14. Astronomical Hypotheses and "Intelligible" Principles

In an effort to bring principles and facts closer together, the Greek astronomers suggested two modifications in the theory of concentric orbits: the theory of eccentrics and the theory of epicycles. According to the first, the earth is not situated exactly in the center of the sun's circular orbit. Under these circumstances, if the sun moves with constant speed, the radius of vision from earth to sun will not be expected to shift with equal angular speed during the year, and the irregularities in the observed motion of the sun on the sphere can be accounted for. The theory of epicycles, on the other hand, assumed that what is moving on a circular orbit around the earth is not the real sun but a "fictitious sun" or "auxiliary geometrical point." The real sun moves along an auxiliary circle, or "epicycle," the center of which is the fictitious sun. The constant speeds of the real and fictitious suns differ, and thus when the motion of one is superimposed on that of the other the result is a single circular motion which varies in speed. This theory of epicycles also accounted for the loops in planetary cycles. It was supposed that while a fictitious Jupiter revolved around the sun in twelve years, the real Jupiter revolved around the fictitious one in a single year. These two motions taken together result in the actual twelve-year cycle with its yearly loops.

The principle that all celestial bodies move in concentric circular orbits around the earth was "intelligible" because it could be derived from the nature of celestial bodies and geometrical figures. The hypotheses of eccentrics and epicycles were not "intelligible" but they accounted for the observed positions of the sun and the planets on the sphere. The choice before the astronomer and the philosopher seemed to be either (1) to stick to "intelligible" principles and resign oneself to their lack of agreement with observed facts or (2) to give up hope of understanding the world by reason alone and be satisfied with "unintelligible" hypotheses which agreed with the facts. For the hypothesis of epicycles was certainly far from "intelligible."

15. Observational and "True" Astronomy

This situation produced a break in the frail chain that joined intelligible principles with observable facts. The universal "science" which was also called "philosophy" split wide open, and the task of "science" was now to think up principles from

which observable facts could be derived as precisely as possible, whether those principles were intelligible or not. In this new sense, the theory of epicycles was "good science."

Plato distinguished very carefully between the two kinds of astronomy and placed them in a definite order of value. In the *Republic,* Plato stresses the point that the observed motions of celestial bodies on the sphere are complicated, disorderly and without beauty. To record them exactly as the observational astronomer does is to perform the lowest function in this branch of knowledge. But the human mind can resolve the disorderly into a sum of simple and regular motions. The movements of the sun on the sphere have been accurately observed for centuries. It is common knowledge that the sun describes an approximate circle on the sphere every day, and that its movements change slowly from day to day. The sum total of these gradually changing movements of the sun is a spiral which is the sum of two circular motions; one daily motion along the equator, and one annual motion along the ecliptic (Zodiac). Plato regarded the spiral as lacking in beauty. But the circular motions were real and beautiful to him. They were derived from a mathematical analysis of the spiral; they were the product of reason, and as such of a higher order of reality than the spiral, which was a product of mere sense perception.

But Plato did not stop there. He believed that the human mind could go farther in its inquiry and seek the causes of these "real" motions. Plato found them in the divine nature of celestial bodies, whose perfect wisdom produced perfect orbits. Thus from mathematical analysis of "observed orbits" came "true astronomy," the system of perfect orbits.

16. Three Degrees of Knowledge in Astronomy

The French scientist, philosopher and historian Pierre Duhem characterizes Plato's ideas on the science of astronomy very aptly:

> There are three degrees of knowledge. The lowest degree is knowledge by sense observation. . . . The supreme degree is knowledge by pure intellect; it contemplates eternal beings and, above all, the sovereign good. Between the first (lowest) and the third (supreme) degree of knowledge is a kind of mixed and hybrid reasoning which occupies the intermediate (second) degree. The knowledge born of this intermediate reasoning is geometrical knowledge. To these

> three degrees of knowledge correspond three degrees of astronomy.
>
> Sense perception is responsible for the astronomy of observation. This kind of astronomy pursues the complicated curves described by the stars . . . and cannot provide any commensurable relation to the arithmetician, nor any definite figure to the geometrician. . . . Through geometric reasoning the mind produces an astronomy which is capable of precise figures and constant relations. This "true astronomy" replaces the erratic paths which observational astronomy attributed to the stars by simple and constant orbits; it produces the complicated and variable appearances which are false knowledge. . . . It approaches knowledge by pure intellect, which reveals the third and supreme astronomy, theological astronomy. . . . In the constancy of celestial motions it sees a proof of the existence of divine spirits which are united with the celestial bodies.

According to Duhem, in short, Plato distinguishes three degrees of astronomy: observational, geometrical, and theological.

The Platonic conception of astronomy makes clear the nature of the split within "philosophy" or "science." Observational and geometrical astronomy together constitute an instrument which can predict the observable positions of the stars, but "theological astronomy" is not necessary or even helpful for this purpose. What it *can* do is to give us a picture of the universe which will be considered a replica of the ideal human society; it can help shape human conduct.

17. "Philosophy" in the Ancient Sense Breaks Up

In order thoroughly to understand the split in philosophy, we must realize that it took place within "geometrical astronomy" itself. The perfection of circular motions could be derived from the divinity of the stars, but the fact that these motions had to be superimposed upon each other in order to produce agreement with sense observations was a human, not a divine, matter. One of Aristotle's commentators, the Greek writer Simplicius, puts the situation this way:

> Plato assumes the principle that the celestial bodies move in a circular motion, uniformly and regularly. He puts to the mathematicians the following problem: What

> circular and regular motions have we to assume as hypotheses in order to save the appearances presented by the motion of the planets?

This is a neat statement of the purpose of such hypotheses as those of the eccentrics and the epicycles; they "save appearances." They do not purport to give us further insight into the nature of the universe nor any example for moral conduct.

A division has taken place. On one side we observe celestial bodies, and employ geometrical figures to support those observations — we save appearances; on the other, we interpret those same geometrical figures as effects of perfect beings. The first approach may be called "astronomy proper," the second the "philosophical interpretation of astronomy."

Mechanics, physics, chemistry, in fact all branches of knowledge underwent a similar division as they developed to the point where observable facts could be derived from abstract principles through logic of mathematics. More and more stress was laid on the necessity for allowing any kind of hypothesis, just so long as it fitted the facts. The slogan was, "save appearances"; science in the modern sense, or "science proper," left "science in the ancient sense" behind, and came into its own.

But the split left a task to be performed: to derive these principles which "saved appearances" from others which revealed the nature of the universe, and might serve as a guide to human conduct. This task became the property of a special field of knowledge, that of "philosophy proper" as opposed to "science proper." The distinction between the two became incorporated into academic life; colleges have a "department" of philosophy and "departments" of science. The former belongs to the area of the humanities and is quite separate and distinct from the area of natural science.

18. The "Philosophical" and the "Scientific" Criterion of Truth

"Science proper" evolved slowly in the Middle Ages, and not much attention was paid to it during that period. But the greatest of the medieval philosophers, Thomas Aquinas, understood the division clearly and was even able to trace its origin to astronomy. St. Thomas writes:

> Reason may be employed in two ways to establish a point: firstly, for the purpose of furnishing sufficient

> proof of some principle as in natural science, when sufficient proof can be brought to show that the movement of the heavens is always of uniform velocity. Reason is employed in another way, not as furnishing a sufficient proof of a principle, but as confirming an already established principle by showing the congruity of its results, as in astrology the theories of eccentrics and epicycles is considered as established because thereby the sensible appearances of the heavenly movements can be explained; not, however, as if the proof were sufficient, for as much as some other theory may explain them.

In contemporary terms, St. Thomas is saying that there are two criteria by which the truth of a scientific statement can be checked: (1) it can be derived logically from self-evident statements and (2) it can be treated as a hypothesis from which we can derive consequences which are then checked with the facts. An example of the first check is the statement that heavenly bodies move in circles at constant speed, which is derived from the statement that heavenly bodies are the most perfect beings and can therefore move only in the most perfect way. The second criterion holds if the consequences of the hypothesis actually check with, say, the evidence of direct sense observation. But this is not a real "demonstration," because the same consequences might well have been deduced from different hypotheses. Using terms which are by now familiar to us, we may call the first criterion "philosophical" and the second "scientific." To Thomas Aquinas, a statement was never unambiguously "demonstrated" by "science proper," only by "philosophy proper," which alone provides the necessary degree of certainty.

19. Science and Philosophy in Newton's Thought

The distinction between these two criteria of scientific truth has survived from the time of St. Thomas to the present day, although in weakened form. The modern physicist would not be satisfied with a statement whose sole virtue lies in the fact that many observable facts can be derived from it. He will also require that the statement be derivable from a system of principles in which he believes more strongly than in any single fact. The scientist of today would certainly not believe that general principles like the conservation of mass, momentum or energy are self-evident, but he would consider them highly plausible. Even

if isolated facts turned up which contradicted these principles, he would not abandon them until he was able to replace them with others of equal generality. In the light of this, St. Thomas' "two criteria" of truth and Aristotle's distinction between the "directly knowable" and the "intrinsically intelligible" prove to be helpful as a frame of reference in our study of the relations between philosophy and science throughout history.

When Galileo and Newton advanced the general principles of "modern science" (the principle of inertia, the law of forces, the law of gravitation, etc.), students of science learned how to hoist heavy loads, aim cannon balls and predict the paths of the planets and comets by deriving methods for doing so from these laws. But one question remained unanswered: are these laws "intelligible"? Do they fulfill the "philosophical" criterion of truth as Aquinas meant it? The "scientist proper" was now satisfied if observable facts could be derived from these laws. But the "philosopher proper" was not satisfied; he demanded "demonstrations," that is, derivation from intelligible principles. Newton himself was well aware of this situation. He realized that the philosophers objected to his theory of gravitation because it "explained" neither gravity nor inertia. In a letter addressed to Leibnitz in a Journal, Newton writes:

> To understand the motions of the planets under the influence of gravity without knowing the cause of gravity is as good a progress in philosophy as to understand the frame of a clock and the dependence of the wheels upon one another without knowing the cause of the gravity of the weight which moves the machine is in the philosophy of the clockwork.

Newton regarded his theory of gravitation as analogous to the description of a clockwork that keeps the planets moving. He agreed that the derivation of the theory from a more general and intelligible principle would contribute to philosophical progress; but as far as "modern science" was concerned, Newton claimed that progress had been made if observable motions could be derived from a law, even though the law were not "intelligible." This is what he meant by his famous statement, "I don't invent hypotheses." He preferred less intelligible laws which agreed with the facts to highsounding hypotheses which did nothing much to "save appearances."

In Newton's time, however, the break between science and philosophy was far from complete, and we find that when faced

with certain questions, he, too, introduced "intelligible" hypotheses, which revealed the "real nature" of the Universe. As an answer to the question why all planets revolve in the same sense and in approximately the same plane, he ascribed these regularities to a divine plan that manifests itself in the structure of the planetary system.

20. The Gradual Loosening of the Tie Between Philosophy and Science

A closer examination of Newton's thought reveals that the emerging split between philosophic and scientific discourse was well in the making. Newton derived the shape of planetary orbits from his law of gravitation through mathematics and did not care whether the law was "intelligible" in itself. But though he rejected any "philosophical" explanation of gravity, he did not refrain from attributing the mutual location of planetary orbits to a plan shaped by an "engineer of the Universe." This idea belongs unquestionably to "philosophy proper."

The development of modern science is characterized by a growing concern with practical applications. Physics developed out of the practical needs of the mechanical and electrical engineer; chemistry supplied principles behind industrial processes like the production of ammonia from nitrogen in the air; biology aided animal husbandry and human medicine. The important thing about the principles developed in these areas of science was that they worked, that they fulfilled the purposes for which they were intended. If they did, then the "scientist in the modern sense" did not much care whether or not they were "intelligible."

As less and less attention was paid to the requirement of intelligibility, it became more difficult to prove or even to understand the truth of scientific principles through mere reasoning and everyday experience. Those principles now tended away from descriptions of the "true" nature of the universe, and as a result were much less suitable as models of "goodness" or the "good society." The connections with ethics and religion were loosening. This did not mean that science could no longer provide directives for human conduct, but simply that the source of those directives was shifted from the science of the physical universe to the science of man: to biology, anthropology, and sociology.

21. Immanuel Kant and the Gap Between Science and Philosophy

Philosophy proper became more and more independent of science proper, and pursued a progress of its own. Its task now was to present a picture of the essential features of the universe, and agreement of philosophical principles with observable facts became a secondary matter, though it was not utterly discarded. The emphasis, however, was now put on the suitability of the world picture as an example for human life; somehow the idea of truth and the idea of goodness had to be correlated. For example, educated people of the nineteenth century habitually discussed science in terms of the "iron law" of physical causality, but human actions were considered somehow exempt from this law; human beings had "freedom of choice." It was hardly conceivable that men could behave morally without this "freedom."

Around 1800, the width and depth of the gap between science and philosophy was emphatically affirmed by the chief representative of German Idealism, Immanuel Kant, one of the outstanding philosophers of all times. Kant was well acquainted with science and possessed extraordinary ability in the analysis of thought; at the same time, he had a sense of high moral responsibility.

Kant stated bluntly that the observable facts of the physical world are completely and satisfactorily described and systematized by "science proper"; "philosophy proper" can never tell us anything about them. It is the function of philosophy to erect a superstructure upon science, not to make statements about physical facts, but rather to ascribe "value" to certain kinds of human action. It was Kant's view that this moral interpretation of the universe is "true" in much the same sense as the statements of science are "true." The inquiry which seeks true statements beyond the domain of "science proper" and tries to obtain these statements from a "philosophical interpretation of science" is called a "metaphysical inquiry." The result of this kind of inquiry is a branch of systematic thought known as "metaphysics," whose function it is to provide us with rules for human conduct, to show us "the good."

But these rules are in no sense derived from an empirical study of the habits of men in a given environment, for that would be "science proper." Kant and his followers held that moral advice can be procured directly from the philosophical

interpretation of the universe, without benefit of sociology or anthropology.

22. Metaphysics Is Practical Rather than Speculative

A few passages from Kant's principal book, the famous *Critique of Pure Reason,* will illustrate how strong his feeling was on the sharp separation between science and philosophy:

> Reason is impelled by a tendency of its nature to go beyond the field of experience and to venture . . . by means of mere ideas to the uttermost limits of all knowledge. Moreover, it finds no rest until it has fulfilled its course and established a systematic whole of knowledge which exists by itself.

Kant was convinced, however, that metaphysics cannot furnish man with knowledge about the world of observable phenomena.

> Whatever discoveries may be made, he continues, they can never be applied to concrete facts, this means, in scientific research.

If this is so, the discoveries of "philosophy proper" are not attained by "speculative" reason. In other words, their purpose is not to give us theoretical knowledge about the world of observable facts; it is rather to serve what Kant called the "practical interests of reason." Let us see what he means by examining his principal examples.

"The highest aims of speculation," he says, "are the freedom of will, the immortality of the soul and the existence of God." But, Kant asks, what interests of reason are served by knowing that the will is free? If we employ scientific methods (speculative reason) to examine human action, we can only discover that it follows causal laws, just as other observable phenomena do. "In other words," writes Kant, "there is no helpful application (of the statement that the will is free) to the world of our experience." Statements like that about free will are therefore, in Kant's terms, "transcendent to speculative reason." Kant proceeds to ask why the proposition that our will is free is so strongly recommended to us by our reason despite its apparent lack of validity in the observable world. He answers that "its importance is probably connected with the practical." But

what is "practical" about this statement, or about another one dealing with the "spiritual" nature of the soul? Just this, that if human actions were determined by "iron laws" of causality, then "moral law" could not possibly have any influence on behavior; it would be useless to direct men to act so as to achieve the "supreme good." Kant was able to resolve the problem created by the ideas of determinism and freedom by postulating two worlds, that of phenomena or experience, and another which lies behind it, the world of "things in themselves." Man as an observable phenomenon is subject to physical causality. As a "thing in itself" he is "free" and can follow the "moral law." Since according to Kant, moral laws would have no meaning if our will were not free, it is "practical" to state that it *is* free; one should take the assertion of a "free will" away from the domain of theoretical or speculative reasoning where it must agree with the facts, and place it in the domain of practical reason, where confirmation by observation is not possible.

Kant's two worlds exemplify a complete split between science and philosophy.

BRIEF BIBLIOGRAPHY FOR THE SOCIOLOGY OF SCIENCE

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Robert K. Merton, *Columbia University*

In broadest outline, the subject-matter of the sociology of science is *the dynamic interdependence* between science, as an ongoing social activity giving rise to empirically confirmed rational knowledge, and the environing social structure. The *reciprocal* relations between science and society are the object of inquiry, as those who have seriously applied themselves to studies in the sociology of science have been forced to recognize. But until very recently, the reciprocity of these relations has received uneven attention, the impact of science upon society eliciting much notice, and the impact of society upon science, little.

Possibly because it is so readily apparent, the impact of science upon the social structure, particularly through its technological by-products, has long been the object of concern if not of systematic study. It is plain to see that science is a dynamic force of social change, though not always of changes foreseen and desired. From time to time, during the last century or so, even physical scientists have emerged from their laboratories to acknowledge, with pride and wonder, or to disown, with horror and shame, the social consequences of their work. The explosion over Hiroshima only verified what everyone knew. Science has social consequences.

But if the consequences of science for society have been long perceived, the consequences of diverse social structures for science have not. Very few physical scientists and not many more social scientists have paid attention to the diverse influences of social structure upon the rate of development, the foci of interest and, perhaps, upon the very content of science. It is difficult to say why there is this reluctance to explore the bearing of its social environment upon science. The reluctance may come from the mistaken belief that to admit the sociological fact would be to jeopardize the autonomy of science. Perhaps it is believed that objectivity, so central a value in the ethos of science, is threatened by the fact that science is an organized social activity, that it presupposes support by society, that the measure of this support and the types of research for which it is

given differ in different social structures, as does the recruitment of scientific talents. There may be something here of the sentiment that science remains the more pure and unsullied if it is implicitly conceived as developing in a social vacuum. Just as the word "politics" now carries for many the connotation of base corruption, so the phrase "social contexts of science" may connote for some physical scientists the intrusion of concerns alien to science proper.

Or perhaps the reluctance comes from the equally mistaken belief that to recognize these connections of science and society is to impugn the disinterested motives of the scientist. Their recognition may seem to imply that the scientist seeks, first and foremost, not the advancement of knowledge but the aggrandizement of self. This is a familiar type of error: the error lies in mistaking the level of motivational analysis for the level of institutional analysis. Scientists may be most variously motivated — by a disinterested desire to learn, by hope of economic gain, by active (or, as Veblen calls it, by idle) curiosity, by aggression or competition, by egotism or altruism. But the same motives in different institutional settings take different social expressions, just as different motivations in a given institutional setting may take approximately the same social expression. In one institutional context, egoism may lead a scientist to advance a branch of science useful for the military arts; in another institutional context, egoism may lead him to work on researches with apparently no military use. To consider how and how far social structures canalize the direction of scientific research is not to arraign the scientist for his motives.

But events of history have succeeded where the studies and writings of social scientists have failed. The course of recent history has made it increasingly difficult, even for scientists secluded in their laboratories and rarely moving about in the larger civil and political society, any longer to neglect the fact that science itself is variously dependent on the social structure. To select but a few of these events, there was first the emergence of Nazi Germany with its dramatic impact upon the nature, quality, and direction of the science cultivated in that country. Rather than recognizing this as an extreme and therefore illuminating case of a more general relationship, rather than seeing this as testimony to the fact that science requires particular forms of social structure in order to follow out its own genius, some physical scientists put this down as an exceptional and pathological case, with no implications for the more general

situation. During the war, however, the marshalling of the forces of science led more scientists to recognize the *interplay* between their science and social structure. And most recently, the politicalizing of science in Soviet Russia has again led others to the same belated conclusion.

With these developments coming so hard on each other's heels as to seem almost one continuous event, many have come to recognize the connections between science and social structure among those who previously thought of these connections, if they thought of them at all, as a figment of Marxist sociology. (In his excellent little book, *On Understanding Science*, for example, James B. Conant refers to "the interconnection between science and society" as a subject "about which so much has been said in recent years by our Marxist friends.") Now, Marx and Engels did indeed set forth the general conception of these interconnections, and deplored the practice of writing "the history of the sciences as if they had fallen from the skies." But since the time of Marx and Engels, there has been distressingly little empirical study of the relations between science and social structure. The same old historical illustrations, grown venerable with age and threadbare with use, have been periodically trotted out to indicate that technological need sometimes leads scientists to focus upon distinctive problems of research. Through such overconformity to the early conceptions of Marx and Engels, piety has been expressed and the *advancement* of the sociology of science has been limited. A pattern of thought and writing has developed which would be appropriate, perhaps, for a religious group where changeless tradition is the thing and ancient revelation must remain intact. But this is scarcely a pattern appropriate to science, including social science, where the founding fathers are honored, not by zealous repetition of their early findings, but by extensions, modifications and, often enough, by rejections of some of their ideas and findings. In the sociology of science, as in other fields, we can profitably return to the wisdom of Whitehead's apothegm: "A science which hesitates to forget its founders is lost."

There is ample institutional evidence of this failure to follow up through empirical research the numerous and now widely recognized problems of the relations between science and the social structure; nowhere among the universities of this country is there an Institute for Research on the Social Relations of Science.

It is to these reciprocal relations between science and its social environment that the following bibliography is devoted.

Since this bibliography is designed to exemplify rather than to exhaust the materials of the sociology of science, it is all the more necessary to delimit its content closely. For one thing, the large literature on scientific method has been omitted as being peripheral rather than central to the subject. Second, and for the same reason, no effort is made to include a working bibliography of the history, as distinct from the sociology, of science, though it is often difficult to draw a useful rather than an arbitrary dividing line between the two. At times, historical accounts are interlarded with sociological analyses of the place of science in a society, and these have on occasion been included. Third, no effort has been made to itemize the large number of works in the "sociology of knowledge" dealing with ideologies, moral beliefs, philosophies, religious conceptions and the like.[1] Fourth, we have omitted biographies of scientists, though these are often instructive as raw materials for the sociologist of science.

The underlying principle of organization has been that of the main spheres of problems in the, as yet, slightly developed sociology of science. A more elaborate document would go on to organize these major categories in turn, according to the place, the time, and the particular sciences under examination. But this further categorization would clearly be inappropriate for the present brief bibliography. It should be noted also that the "sciences" to which reference is here made include mathematics and medicine, as well as the natural and physical sciences more strictly construed. On occasion, pertinent studies of the social aspects of technology are also included. And finally, though to a limited degree, studies of the interplay between society and social science also find a place.

Many of the references do not fall neatly and exclusively into one or another of the categories in the classification adopted here. In such instances, an effort is made to classify each item in the category to which it is primarily devoted.

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[1] Brief bibliographies of the sociology of knowledge will be found in Karl Mannheim, *Ideology and Utopia,* and in Harry E. Barnes, Howard Becker and Frances Becker (eds.), *Contemporary Social Theories* (New York, 1940).

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6.4. W. V. Quine, *Methods of Logic,* New York 1950, xx + 264 pp. Recommended as a text-book for students of philosophy.

6.5. I. M. Bocheński, *Nove Lezioni di Logica Simbolica,* Rome 1938, 184 pp.

6.6. I. M. Bocheński, *Précis de Logique Mathématique,* Bussum 1949, 90 pp. An excellent outline suffers from faults due to excessive condensation.

6.7. Rudolf Carnap, *Abriss der Logistik,* Vienna 1929, vi + 114 pp. Very condensed, intended to introduce the student rapidly to the technique and applications of mathematical logic.

6.8. Robert Feys, *De Ontwikkeling van het Logisch Denken,* Antwerp and Nijmegen 1949, 220 pp. Excellent historical introduction.

6.9. Robert Feys, *Logistiek, Geformaliseerde Logica,* vol. I, Antwerp and Nijmegen 1944, 340 pp. First volume of a proposed comprehensive manual.

6.10. W. V. Quine, *O Sentido da Nova Lógica,* São Paulo 1944, 252 pp. An excellent text-book and expository work, philosophically oriented.

6.11. D. Hilbert and W. Ackermann, *Grundzüge der Theoretischen Logik,* 3rd edn., Berlin-Göttingen-Heidelberg 1949, viii + 155 pp. *Principles of Mathematical Logic,* unauthorized English translation of the second edition, New York 1950. Standard text-book for students of mathematics. The third German edition is recommended.

6.12. Heinrich Scholz, *Vorlesungen über Grundzüge der Mathematischen Logik,* 2 vols., Münster i. W. 1949; revised edition, Münster i. W. 1950-51. An intermediate mathematical text-book, like 6.11 especially valuable as an introduction to 6.18.

6.13. Rudolf Carnap, *Logische Syntax der Sprache,* Vienna 1934, xi + 274 pp. *The Logical Syntax of Language,* revised and enlarged English edition (translation by Amethe von Zeppelin), New York and London 1937. An account of the fundamentals of mathematical logic (less elementary than 6.7), and at the same time of the author's philosophical views. The latter have since undergone important modifications—cf. 32.4, 33.5, 32.6.

6.14. W. V. Quine, *Mathematical Logic,* New York 1940, xiii + 348 pp.; revised second printing, Cambridge, Mass., 1947, xi + 340 pp.; revised edition, Cambridge, Mass., 1951, xii + 346 pp. A relatively advanced text-book, and a treatise on a system due to the author as an alternative to type theory or set theory. The edition of 1951 is recommended.

6.15. Jacques Herbrand, *Recherches sur la Théorie de la Démonstration* (dissertation Paris 1930), Warsaw 1930, 128 pp.

6.16. Andrzej Mostowski, *Logika Matematyczna,* Warsaw and Breslau 1948, viii + 388 pp. Excellent advanced text-book for students of mathematics. An English translation is planned.

6.17. Alonzo Church, *Introduction to Mathematical Logic,* part I, Princeton, N. J., 1944, vi + 118 pp. As planned, the complete work is a systematic treatise, and text-book for students

with substantial mathematical background. A much enlarged and revised edition of part I is in process of publication.

6.18. D. Hilbert and P. Bernays, *Grundlagen der Mathematik,* 2 vols., Berlin 1934 and 1939. Comprehensive treatise of mathematical logic and Hilbertian proof theory.

7. PROPOSITIONAL CALCULUS.

7.1. E. L. Post, *Introduction to a general theory of elementary propositions,* AJM, vol. 43 (1921), pp. 163-185.

7.2. Paul Bernays, *Axiomatische Untersuchung des Aussagen-Kalkuls der "Principia Mathematica."* Mathematische Zeitschrift, vol. 25 (1926), pp. 305-320.

7.3. Jan Łukasiewicz, *Elementy Logiki Matematycznej,* Warsaw 1929, viii + 200 pp.

7.4. Jan Łukasiewicz and Alfred Tarski, *Untersuchungen über den Aussagenkalkül,* Comptes Rendus des Séances de la Société des Sciences et des Lettres de Varsovie, class III,[4] vol. 23 (1930), pp. 30-50.

7.5. László Kalmár, *Über die Axiomatisierbarkeit des Aussagenkalküls,* Acta Scientiarum Mathematicarum, vol. 7 (1934-5), pp. 222-243.

7.6. W. V. Quine, *Completeness of the propositional calculus,* JSL, vol. 3 (1938), pp. 37-40.

7.7. Jan Łukasiewicz, *Die Logik und das Grundlagenproblem,* Les Entretiens de Zurich,[5] edited by F. Gonseth, Zurich 1941, pp. 82-108.

7.8. Stanisław Jaśkowski, *Trois contributions au calcul des propositions bivalent,* Studia Societatis Scientiarum Torunensis, sectio A, vol. 1 (1948), pp. 1-15.

7.9. Leon Henkin, *Fragments of the propositional calculus,* JSL, vol. 14 (1949), pp. 42-48. See also Maurice L'Abbé, JSL, vol. 16, pp. 43-45.

Also 6.1 (2nd English edn.), 6.11, 6.15, 6.17, 6.18.

8. FUNCTIONAL CALCULUS OF FIRST ORDER.

8.1. Kurt Gödel, *Die Vollständigkeit der Axiome des logischen Funktionenkalküls,* Monatshefte für Mathematik und Physik,[6] vol. 37 (1930), pp. 349-360.

8.2. Leon Henkin, *The completeness of the first-order functional calculus,* JSL, vol. 14 (1949), pp. 159-166.

8.3. Gonzalo Zubieta R., *Sobre el Cálculo Funcional de Primer Orden* (dissertation Mexico 1950), vi + 35 pp.

8.4. GONZALO ZUBIETA R., *Sobre la substitución de las variables funcionales en el cálculo funcional de primer orden,* Boletin de la Sociedad Matemática Mexicana, vol. 7 (1950), pp. 1-21.

Also 6.11, 6.12, 6.15, 6.16, 6.17, 6.18, 26.2, 26.3, 26.5. See further 9 and 11.

9. DECISION PROBLEM OF THE FUNCTIONAL CALCULUS OF FIRST ORDER.

9.1. JACQUES HERBRAND, *Sur le problème fondamental de la logique mathématique,* CRV, vol. 24 (1931), pp. 12-56.

9.2. KURT GÖDEL, *Zum Entscheidungsproblem des logischen Funktionenkalküls,* MMP, vol. 40 (1933), pp. 433-443.

9.3. ALONZO CHURCH, *A note on the Entscheidungsproblem,* JSL, vol. 1 (1936), pp. 40-41, 101-102.

9.4. LÁSZLÓ KALMÁR, LÁSZLÓ KALMÁR and JÁNOS SURÁNYI, *On the reduction of the decision problem,* JSL, vol. 4 (1939), pp. 1-9, vol. 12 (1947), pp. 65-73, vol. 15 (1950), pp. 161-173.

9.5. JÁNOS SURÁNYI, *Zur Reduktion des Entscheidungsproblems des logischen Funktionenkalküls* (Hungarian with German abstract), Matematikai és Fizikai Lapok, vol. 50 (1943), pp. 51-74. See review by Rózsa Péter in JSL, vol. 9 (1944), pp. 22-24.

9.6. JÁNOS SURÁNYI, *Reduction of the decision problem to formulas containing a bounded number of quantifiers only,* XCP, pp. 759-762.

9.7. LÁSZLÓ KALMÁR, *Contributions to the reduction theory of the decision problem, First paper,* Acta Mathematica Academiae Scientiarum Hungaricae, vol. 1 no. 1 (1950), pp. 64-73.

9.8. ALONZO CHURCH, *Special cases of the decision problem,* Revue Philosophique de Louvain, vol. 49 (1951), pp. 203-221. An expository summary of solutions in special cases. Errata: in each of the two lines of the displayed formula on page 206, insert three dots after the last bold dot in the line; and six lines below the formula, for μ read ν. An error regarding Case 7 (p. 210) is corrected by Ackermann, JSL, vol. 17, pp. 73-74.

Also 6.11, 6.15, 6.17, 6.18, 14.3. See further 10.

10. DECISION PROBLEMS IN GENERAL.

10.1. ALFRED TARSKI, *On essential undecidability* (abstract), JSL, vol. 14 (1949), pp. 75-76.

10.2. W. V. QUINE, *On decidability and completeness,* Synthese, vol. 7 (1948-9), pp. 441-446.

10.3. ANTONI JANICZAK, *A remark concerning decidability of complete theories,* JSL, vol. 15 (1950), pp. 277-279.

Results concerning various particular decision problems (other than that of the functional calculus of first order) are here omitted for lack of space.

11. ABSOLUTE LOGIC.

Papers in Russian by D. A. Bočvar and P. S. Novikov. See reviews in JSL, vol. 11, p. 129 (second review); vol. 12, p. 27; vol. 13, p. 170. The "absolute logic" of Bočvar offers an interesting fresh approach to the problem of the logical paradoxes, though his results so far obtained in connection with it are of preliminary character and not of major importance. The principal result claimed (without proof) by Novikov is in error, at least as reported in JSL—being subject to the counter-example $(Ep_2)\ (x_2, x)\ \left[p_2\ (x_2, x) \equiv \sim x_2\ (x, x)\right]$, as pointed out by A. A. Barnes, Jr.

12. THEORY OF TYPES.

12.1. Alfred Tarski, *Einige Betrachtungen über die Begriffe der ω-Widerspruchsfreiheit und der ω-Vollständigkeit*, MMP, vol. 40 (1933), pp. 97-112.

12.2. Gerhard Gentzen, *Die Widerspruchsfreiheit der Stufenlogik,* Mathematische Zeitschrift, vol. 41 (1936), pp. 357-366. Detailed statement of a consistency proof for type theory without axiom of infinity (previously given more briefly by Herbrand 6.15, Tarski 12.1).

12.3. W. V. Quine, *On the theory of types,* JSL, vol. 3 (1938), pp. 125-139.

12.4. Alonzo Church, *A formulation of the simple theory of types,* JSL, vol. 5 (1940), pp. 56-68.

12.5. Leon Henkin, *Completeness in the theory of types,* JSL, vol. 15 (1950), pp. 81-91.

Also 1.3, 1.27, 1.28, 5.18, 5.19, 6.7, 6.11, 6.13, 6.15, 6.16, 6.17, 13.1, 21.3, 24.2.

13. GÖDEL'S INCOMPLETENESS THEOREM.

13.1. Kurt Gödel, *Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme,* MMP, vol. 38 (1931), pp. 173-198.

13.2. Barkley Rosser, *Extensions of some theorems of Gödel and Church,* JSL, vol. 1 (1936), pp. 87-91.

13.3. Barkley Rosser, *An informal exposition of proofs of Gödel's theorems and Church's theorem,* JSL, vol. 4 (1939), pp. 53-60. A non-technical sketch with deliberate sacrifice of accuracy in favor of (rough) intelligibility.

Also 6.10 (an informal sketch), 6.13, 6.14, 6.16, 6.18, 14.1, 14.6, 21.7 (brief semi-formal outline).

14. RECURSIVE FUNCTIONS AND RELATED TOPICS.

14.1. S. C. KLEENE, *General recursive functions of natural numbers,* Mathematische Annalen, vol. 112 (1936), pp. 727-742.

14.2. ALONZO CHURCH, *An unsolvable problem of elementary number theory,* AJM, vol. 58 (1936), pp. 345-363.

14.3. A. M. TURING, *On computable numbers, with an application to the Entscheidungsproblem,* Proceedings of the London Mathematical Society, ser. 2 vol. 42 (1936-7), pp. 230-265, and vol. 43 (1937), pp. 544-546.

14.4. E. L. POST, *Finite combinatory processes — formulation 1,* JSL, vol. 1 (1936), pp. 103-105.

14.5. A. M. TURING, *Computability and λ-definability,* JSL, vol. 2 (1937), pp. 153-163.

14.6. S. C. KLEENE, *Recursive predicates and quantifiers,* Transactions of the American Mathematical Society, vol. 53 (1943), pp. 41-73.

14.7. E. L. POST, *Formal reductions of the general combinatorial decision problem,* AJM, vol. 65 (1943), pp. 197-215.

14.8. E. L. POST, *Recursively enumerable sets of positive integers and their decision problems,* Bulletin of the American Mathematical Society, vol. 50 (1944), pp. 284-316.

14.9. S. C. KLEENE, *On the interpretation of intuitionistic number theory,* JSL, vol. 10 (1945), pp. 109-124.

14.10. DAVID NELSON, *Recursive functions and intuitionistic number theory,* Transactions of the American Mathematical Society, vol. 61 (1947), pp. 307-368, 556.

14.11. ANDRZEJ MOSTOWSKI, *On definable sets of positive integers,* Fundamenta Mathematicae,[7] vol. 34 (1947), pp. 81-112.

14.12. ANDRZEJ MOSTOWSKI, *On a set of integers not definable by means of one-quantifier predicates,* Annales de la Société Polonaise de Mathématique, vol. 21 (1948), pp. 114-119.

14.13. RÓZSA PÉTER, *Rekursive Funktionen,* Budapest 1951, 206 pp.

14.14. S. C. KLEENE, *Introduction to Metamathematics,* forthcoming book.

Also 6.18, 24.2, 25.1. See further 10.

15. FOUNDATIONS OF ARITHMETIC.

15.1. THORALF SKOLEM, *Begründung der elementaren Arithmetik durch die rekurrierende Denkweise ohne Anwendung scheinbarer Veränderlichen mit unendlichem Ausdehnungsbereich,* Skrifter Utgift av Videnskapsselskapet i Kristiania, 1923, no. 6, 38 pp.

15.2. JACQUES HERBRAND, *Sur la non-contradiction de l'arithmétique,* Journal für die Reine und Angewandte Mathematik, vol. 166 (1931-2), pp. 1-8.

15.3. THORALF SKOLEM, *Über die Nicht-charakterisierbarkeit der Zahlenreihe mittels endlich oder abzählbar unendlich vieler Aussagen mit ausschliesslich Zahlenvariablen,* FM, vol. 23 (1934), pp. 150-161. (See also 20.1, 20.2.)

15.4. WILHELM ACKERMANN, *Zur Widerspruchsfreiheit der Zahlentheorie,* Mathematische Annalen, vol. 117 (1940), pp. 162-194.

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16. INFORMAL AXIOMATIC METHOD IN THE FOUNDATIONS OF MATHEMATICS.

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Also 1.3, 6.17 (new edition).

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17.1. BERNARD BOLZANO, *Paradoxien des Unendlichen,* Leipzig 1851; reprinted Leipzig 1920, with commentary by Hans Hahn. *Paradoxes of the Infinite,* English translation (with historical introduction) by D. A. Steele, London and New Haven 1950, ix + 189 pp.

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17.5. WACŁAW SIERPIŃSKI, *Leçons sur les Nombres Transfinis,* Paris 1928, vi + 240 pp.; reprinted Paris 1950.

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18.5. HAO WANG, *Remarks on the comparison of axiom systems,* Proceedings of the National Academy of Sciences of the U. S. A., vol. 36 (1950), pp. 448-453. See review by Andrzej Mostowski in JSL, vol. 16 (1951), pp. 142-143.

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Also 5.17, 20.1, 20.4, 31.3.

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19.2. ADOLF LINDENBAUM and ANDRZEJ MOSTOWSKI, *Über die Unabhängigkeit des Auswahlaxioms und einiger seiner Folgerungen,* CRV, vol. 31 (1938), pp. 27-32.

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20.2. ANDRZEJ MOSTOWSKI, *On absolute properties of relations,* JSL, vol. 12 (1947), pp. 33-42.

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21.2. David Hilbert, *Die Grundlagen der Mathematik,* with a note by Paul Bernays and a reply on behalf of mathematical intuitionism by Hermann Weyl, Abhandlungen aus dem Mathematischen Seminar der Hamburgischen Universität, vol. 6 (1928), pp. 65-92. Reprinted as no. 5 of Hamburger Mathematische Einzelschriften, Leipzig 1928. Reprinted without the notes by Weyl and Bernays as Anhang IX of the seventh edition of Hilbert's *Grundlagen der Geometrie.* The material should be read in the light of later developments as set forth in 6.18 (in particular the results of Gödel 13.1).

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21.6. E. W. Beth, *Wijsbegeerte der Wiskunde,* 2nd edn., Antwerp and Nijmegen 1948, 387 pp.

21.7. Hermann Weyl, *Philosophy of Mathematics and Natural Science,* Princeton 1949, x + 311 pp.
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22. MATHEMATICAL INTUITIONISM.

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26.2. GERHARD GENTZEN, *Untersuchungen über das logische Schliessen,* Mathematische Zeitschrift, vol. 39 (1934-5), pp. 176-210, 405-431.

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[1] These Proceedings will be referred to below (throughout this bibliography) as "XCP."

[2] This periodical will be referred to below as "JSL."

[3] This periodical will be referred to below as "AJM."

[4] Class III of this periodical will be referred to below as "CRV."

[5] This book will be referred to below as "EdZ."

[6] This periodical will be referred to below as "MMP."

[7] This periodical will be referred to below as "FM."

SOME SIGNIFICANT TRENDS TOWARD INTEGRATION IN THE SCIENCES OF MAN[1]

LAURA THOMPSON

It is generally agreed that the basic assumptions, methodologies and goals of a unified and mature science of man have not yet been formulated systematically in a way to gain general acceptance, much less in a way to be applied to the crucial problems of our time. Without such systematic formulation it is easy to overlook certain convergent discoveries and trends toward integration in the many academically-unrelated disciplines that deal with man, or to ignore their significance. The purpose of this extremely brief bibliography is: 1. to call attention to some trends in the human disciplines which appear to be especially significant regarding the eventual emergence of a systematic, unified science of man; and 2. to illustrate the thesis by means of a limited number of references, especially to recent publications in the English language. It should be emphasized that both thesis and documentation are intended to be merely suggestive and illustrative rather than definitive. Obviously no attempt has been made at complete coverage of the vast relevant literature. It is hoped, however, that even such a brief presentation may help to clarify certain significant trends and to stimulate further research in these directions.

TRENDS TOWARD INTEGRATION IN THEORETICAL APPROACH

1. *The sciences of man are natural sciences.* The biological base of the human disciplines is receiving more and more attention, not only in the biological sciences (Darwin, Geddes and Thomson p. 147f.) including genetics (Dobzhansky, Sinnott et al. 1950), physiology (Cannon, Lillie, Pavlov, p. 395f., Sherrington), physical anthropology (Boyd, Hooton, Montagu), social and cultural ecology, ethnogeography and ethnobotany (Adams 1935, Allee 1938, Carter, Malin, Mumford, Sears 1939), and nutrition (Postmus and VanVeen), but also in the psychological and the social sciences (Cantril 1950, Cameron, Frank 1951, Cameron, Haring, Hebb, Hunt ed., Malinowski, Murphy, Sheldon 1940, 1942, 1949). An organic approach rather than

[1] I am indebted to John Collier, Charles Morris and David Bidney for helpful comments on the manuscript.

a "superorganic" or "superpsychic" approach is being stressed (Bidney 1947, 1949b, Mumford p. 300f., Sapir 1917), and the traditional dual division between "natural" and "social" sciences is becoming outmoded (Whyte p. 17). Related to this trend is an increasing interest in cooperative processes in communities and societies (Bishop, Deets, Haskell ed., M. Mead ed.), and a growing conviction that cooperation is a basic principle of organic life (Allee 1938, Kropotkin, Montagu).

2. *The significant unit of research in the sciences of man is a human event in space-time.* Whether the focus be an individual organism or a group of organisms, there is a trend toward viewing the significant unit of research in the human sciences as a multidimensional human event in space-time rather than, e.g., as an object or thing, a "trait" or a pattern, or as an aggregation of objects, "traits", or patterns simply located in an environment as though in a container or mold (Bentley 1926 p. 48f., Frank 1951 p. 31f., Herrick p. 163f., 206f., Whitehead 1926 p. 72f.). From this emerging viewpoint a pattern or a system or a process, whether it be of overt behavioral activities, of institutions, symbols, norms or goals, represents the unknown (e.g., x) to be discovered, and the scientific problem is formulated in terms of its multidimensional exploration (see 3 below). The relevant trend is toward recognizing, as the given significant unit of research, not the pattern or the process itself but rather the patterned or processual event or happening, including its prospective (moving forward into the future) phases and its retrospective (historical) phases.

Whether reference be made to a psychosomatic or a personality unit (Ames, Herrick, Meyer, Murphy), to a local region or community (Malin, Sears 1949), to a society (Lewin 1948), or to a culture (Benedict 1934, Malinowski, Thompson 1950), emphasis is increasingly on the organism-environment event or happening as a complex whole. The "known" and the "knower" are conceived as profoundly intervolved (Ames, Cantril 1950, Dewey and Bentley), and transactional rather than merely reciprocal or interactional relationships are beginning to be stressed (Bentley 1950, Cantril et al. 1949; Frank 1951). Closely related to these developments are the new action-research and operational-research methodologies involving a team composed of scientists from various disciplines, administrators, and laymen working together to solve a practical problem (Bishop, Collier 1945, Dobbs, Lewin 1948, ch. 13, Thompson 1951b, p. 29f.).

3. *Significant problems in the sciences of man deal with the*

inner structural relations of an organized dynamic "field". A significant tendency is to view the multidimensional human event in space-time as a dynamic "field" and to view the scientific problem as the discovery of the structural organization of this "field" (Kluckhohn and Murray ed., Korzybski, Lewin 1951). (For dangers to be avoided in using the "field" approach see Bentley 1950.)

4. *The trend, in terms of the present thesis, is away from investigating a human problem merely from a single viewpoint* (e.g., the "economic", the somatic, the Freudian, the overt behavioral) *and toward perceiving the human event from many viewpoints simultaneously* ("inside" and "outside", "above" and "below", "far" and "near") *so that the relationships between its various aspects and its inner and outer form may be discovered* (see 6 below; also Adams 1935, Bentley 1926 p. 57f., Collier 1947, Giedion, Lee 1950, Malin, Mannheim, Parsons and Shils, Thompson 1950, Thurnwald, Wittfogel and Fêng). One important effect of this trend is that the sex factor is being placed in proper relation to other factors equally important (Allee 1931 p. 4). Furthermore, regarding the psychological dimension, in this type of research the psychiatric approach is beginning to take precedence over the Freudian psychoanalytical approach (Chrisholm, Frank 1948, Hallowell 1950, Hunt ed., A. H. Leighton, M. Mead 1939, Meyer, Sullivan, Thompson 1951b).

The above-mentioned trends reveal, throughout the fundamental sciences of man, a convergence in basic theoretical approach which manifestly is related to recent trends in physics and mathematics (Bentley 1926 pt. 1, Einstein and Infeld, Whitehead 1926), in logic (Dewey 1938, Dewey and Bentley, Kantor), and in modern art and architecture (Giedion, Mumford).

Trends Toward Integrative Multidiscipline Research

5. *The new approach, especially concentration on multidimensional human events in space-time, on transactional relationships, and on perception from many viewpoints simultaneously, together with the imperative need to solve practical problems* (Lynd), *has necessitated the crossing of barriers between traditional academic disciplines dealing with mankind.* Indeed, artificial barriers are breaking down under the clinical test and a shakeup of the human disciplines is going forward. From the shakeup are emerging a number of key dimensions or vantage

points from which to view the human event in historical and areal perspective (looking both "backward" and "forward" in time and in all directions "inside" and "outside" in space). These are taking form as the basic integral dimensions of the future unified science of mankind. Although still in the formative stage, for purposes of the present thesis they may be conveniently designated as follows (Frank 1951, Morris 1948 p. 30, Thompson 1950, 1951 ch. 8): *the ecologic dimension*—society-nature transactions; *the somatic dimension*—somatic transactions; *the social dimension*—interpersonal and intergroup transactions; *the psychic dimension*—psychological transactions; *the symbolic dimension*—symbolic and semantic transactions including language, ceremonials, arts and crafts, music, mythology, folklore, sciences, etc. (see Cassirer p. 24f., Morris 1946); *the core values dimension*—basic evaluational transactions (see Frank 1948, p. 365f., Kluckhohn 1949, Murphy p. 815, Parsons and Shils, Thompson 1951b ch. 8). Parenthetically it should be noted that alongside the major divisions outlined above, attempts are being made in the direction of developing a more adequate philosophy of the science of mankind (see, e.g., Bidney 1949a, Cassirer, Dewey 1934, 1938, Frank 1951, Herrick, Lillie, G. H. Mead, Northrop 1947, Smuts, Whitehead 1925, 1933).

6. *Significant attempts are being made to investigate the inner structural relations between two or more of these basic dimensions of the emergent science of mankind.* For example, inquiries into the relations between the following basic dimensions are going forward, to mention only a few illustrations:[2] ecologic and somatic (Monge); ecologic and social (Carter, Polanyi, Firth); ecologic, somatic, social (Postmus and Van-Veen); ecologic, social, symbolic (Giedion, Herskovits, Kroeber, Malin, Mumford); ecologic, social, symbolic, core values (Deets, Kluckhohn and Leighton, Wittfogel and Fêng); ecologic, somatic, social, psychic, symbolic (Hunt ed., Joseph and Murray); ecologic, social, psychic, symbolic, core values (Burckhardt, Hallowell 1950, Thurnwald); ecologic, somatic, social, psychic, symbolic, core values (Collier 1947, Joseph et al., Thompson 1950); somatic and psychic (Hebb, Lillie, Sheldon 1940, 1942, Sinnott); somatic, social, psychic (G. H. Mead, Sheldon 1949); somatic, social, symbolic (Morris 1946, Wiener); somatic, social, psychic, symbolic, core values (A. H. Leighton); social and psychic

[2] It should be emphasized that the attempts cited and their categorization are merely suggestive and by no means definitive.

(Moreno, Murdock); social, psychic, symbolic (DuBois, Fromm 1941, Kardiner et al., Leighton and Kluckhohn, Linton, Overstreet, Sapir 1949); social, psychic, symbolic, core values (Benedict 1934, 1946, Frank 1948, Fromm 1949, Jaeger, Lee 1949, 1950); social, symbolic, core values (Malinowski, Morris 1948, Northrop 1946, Whorf); social, psychic, core values (Parsons and Shils); symbolic and core values (Alexander, Korzybski).

These and other attempts have led in the direction of multidiscipline cooperative research in the sciences of man (see 6 above), and to the development of integral depth analysis of complex whole human events (see 6).

7. *The new approach has revealed the need of field methods and laboratory techniques of requisite precision and penetration* (Adams 1935, Freud, Hallowell 1949, Kluckhohn and Murray ed., Lewin 1948, 1951, Malin, Malinowski, Murdock, Radcliffe-Brown, Redfield), and has led to a more critical investigation of the whole perceptive process (Ames, Hebb, Korzybski, Lee 1950, Lewin 1948 p. 56f., Mannheim p. 212f., Murphy ch. 14).

8. *The development of properly precise and penetrating methods and of multidimensional crossdiscipline research has necessitated a thoroughgoing revision of traditional concepts* (Bentley 1926 p. 57f., Bidney 1947, 1949b, Cantril 1950, Dewey and Bentley, Frank 1951, Korzybski, Murphy, Parsons and Shils, Whitehead 1926, 1933).

9. *There is increasing interest in the formative processes* (Adams 1940, Malin, Smuts, Whyte p. 21) *whereby eco-cultural, social, and psychosomatic wholes are integrated, especially in the directiveness of organic activities* (Cannon, Lillie, Russell, Sears 1939, 1949, Sinnott), *the purposiveness of individual, social and cultural processes* (Ames, Bentley 1926, Malinowski p. 52f., Overstreet, Redfield 1941 p. 141f., Tolman), *and in human creativity* (Bergson, Cassirer p. 223f., Morris 1948, Wertheimer). There is increasing recognition that the processes of adaptation and adjustment to the environment cannot of themselves completely account for such wholes (Hallowell 1950, Kluckhohn 1949, Overstreet p. 73), nor can adaptation plus organic integration. Over and above these processes there is being identified a distinctively *human* integrating process, a symbolic process tending toward the formation of balanced, whole, self-regulating personalities and communities (Burke, Cassirer, Jaeger, Malinowski ch. 5). The fundamentally esthetic nature of this process (Alexander, Cantril 1950, Dewey 1934) and also its inherent logic (Sorokin v. 1 p. 18f.) are receiving increasing attention.

10. As an outgrowth of all these developments, *the crucial importance of basic, emotionally-tinged attitudes and core values is being more and more recognized in the life sciences and in practical everyday living problems* (Adams 1940, Ames, Bateson, Benedict 1934, 1946, Bishop, Cantril 1950, Collier 1947, Deets, Frank 1948, 1951, Jaeger, Kluckhohn 1949, Lee 1949, 1950, Morris 1948, Overstreet, Piaget, Sears 1939, Sorokin, Thompson 1950, Whitehead 1933).

Unfortunately, space limitations preclude discussion of how the new integral multidiscipline approach in the sciences of man is being applied to the practical problems of our time. The present writer has dealt briefly with this aspect of the thesis elsewhere (Thompson 1951a).

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